

CLAIMS

1. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, applicable to two-way communication over the electricity network between a head-end a various users that includes the means to add and extract a cyclic prefix to the OFDM symbols, including interpolators and decimators in the transmission and reception systems of the equipments and digital band translation, and which comprises the sending of synchronization sequences in the information sent via the downstream channel which runs from the head-end to the users, to provide synchronization in frequency and time in reception, and characterized in that the process comprises the generation of synchronization sequences by means of two identical synchronization symbols (16) periodically transmitted from the head-end equipment by the downstream channel to all the user equipments which detect said synchronization sequences in reception and selectively estimate and correct the sampling frequency in the analog/digital converters (7) that are included in the receivers in the user equipments, or carry out a re sampling of the digital signal, synchronization in frequency, and simultaneously estimate the moment each OFDM symbol begins, synchronization in time.

2. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 1, characterized in that the detection of the synchronization sequences occurs by using maximum likelihood criteria so that time synchronization begins from the calculation of the maximum correlation of the samples of two received symbols, and this maximum becomes the mid point in the flat zone for the correlation

peak, whose size in number of samples is equal to the number of samples of the cyclic prefix without intersymbol interference, ISI, and carrying out the frequency synchronization, by means of calculating the angle of this correlation in the moment determined as maximum correlation.

3. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 2, characterized in that the correlation maximum is calculated by detecting the correlation peaks that surpass a threshold that corresponds to multiplying the power by a constant C, where the value of this maximum is taken to be the mid point of the flat zone in the correlation peak whose size in number of samples is equal to the number of samples of the cyclic prefix without intersymbol interference, ISI; where the value of the constant C is fixed to minimize the probability of producing false alarms, and the correlation is calculated by means of the following algorithm:

$$\gamma(m) = \sum_{k=m}^{m+l-1} r(k) r^*(k+n)$$

and the power is calculated by means of the following algorithm:

$$\xi(m) = \frac{1}{2} \sum_{k=m}^{m+l-1} (|r(k)|^2 + |r(k+n)|^2) \cong \sum_{k=m}^{m+l-1} |r(k)|^2$$

where $\gamma(m)$ is the correlation at the moment of the sample m and $\xi(m)$ the power at the moment of the sample m, $r(k)$ is the sample received in the moment k, $r^*(k+n)$ is the conjugation of the sample received in k+n, $n=N+L$ and $l=n$, where N is the number of samples of one of the symbols in the synchronization sequence and L the number of cyclic

prefix samples.

4. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claims 2 and 3, characterized in that the calculation of correlation and power is undertaken iteratively, storing the samples and preferably the partial products of the current sample by the conjugated sample that arrived $N+L$ samples before, for the calculation of the correlation and the power by means of the following algorithms:

$$P(d) = P(d-1) + (r_d r_{d-(N+L)}^*) - (r_{d-N} r_{d-(N+L)-N}^*)$$

$$R(d) = R(d-1) + r_d^2 - r_{d-N}^2$$

where $P(d)$ is the correlation, $R(d)$ the power, r_d the current sample, r_{d-N} the sample that arrived at the receiver N samples before, $r_{d-(N+L)}^*$ the complex conjugation of the sample received $N+L$ samples previously and $r_{d-(N+L)-N}^*$ the complex conjugation of the samples received $2N+L$ samples previously.

5. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 3, characterized in that once frequency error is less than a pre established threshold, only the real part of the correlation is used to simplify calculation.

6. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 3, characterized in that detection of the synchronization sequence is carried out by comparing the value of the correlation with the power value multiplied by a value C to minimize the probability of a

false alarm, so that synchronization sequence and the optimum moment for the sample are searched for when the condition $|\gamma| > C\xi$ is given, where C is a factor that multiplies the power so that this product may be used as a threshold.

7. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 1, characterized in that the two identical synchronization symbols are selectively constituted for fixed or pseudorandom information.

8. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 1, characterized in that synchronization of the sampling frequency and synchronization of time in the receivers comprise an acquisition stage and a tracking stage, where the acquisition stage includes a search for a determined number of synchronization sequences, a rough frequency error correction and the move to the tracking stage for both synchronizations.

9. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 8, characterized in that the acquisition stage for the time synchronization comprises a waiting stage to detect a synchronization sequence with a determined number of symbols or synchronization sequences in the position, moments, expected, before moving on to the tracking stage to reduce the probability of acquisition of synchronization due to a false alarm.

10. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM

MODULATION, according to either of Claims 8 or 9, characterized in that following the acquisition of the time synchronization the process comprises a follow up stage for the time synchronization which consists of detecting the synchronization sequences sent by the downstream channel to the users, keeping account of the number of sequences not received, where in case a certain established limit is surpassed causes the process to return to the time acquisition stage.

11. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 8, characterized in that in the time synchronization tracking stage, a modification of the moment in which the OFDM symbol begins occurs each time a new synchronization sequence arrives; this modification being undertaken by means of the variation in the group of samples applied in transformation of the signals from the time domain to the frequency domain as foreseen by the user receivers and, which may produce a change of phase or rotation in the demodulated constellations that is corrected by means of equalization, and for which, equalization sequences are transmitted, preferably after synchronization sequences.

12. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 8, characterized in that the frequency synchronization acquisition stage is suppressed in the case where the oscillator, which is used to provide the sampling frequency in the analog/digital converter of the receiver, is sufficiently precise.

13. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM

MODULATION, according to Claim 8, characterized in that the frequency synchronization acquisition stage takes place after the time synchronization acquisition stage and said stage includes the estimation of sampling frequency error beginning from the correlation angle in the maximum moment of this metric, using the moment situated in the centre of the flat zone of the maximums of the metric, according to the following algorithm:

$$\angle \bullet(\bullet_{\text{opt}}) = -2\pi f_c M(N+L) \left(\frac{\Delta f_s}{f_s + \Delta f_s} \right)$$

where M is the interpolation and decimator factor, f_c the carrier frequency, f_s the sampling frequency and Δf_s the sampling frequency error; it further comprises a compensation stage for this error by means of a frequency corrector element, selectively consisting of an oscillator controlled by voltage (28) or a re sampler (27) with its associated filters (12), and beginning from the previous algorithm it calculates the angles of the correlation in the moment in which this metric is maximum, for which it calculates the arctangent of the ratio of the imaginary part and the real part of the correlation and obtaining Δf_s by the algorithm mentioned previously, these steps being repeated iteratively until the estimation of sampling frequency error is less than a certain threshold.

14. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claims 8 or 13, characterized in that the frequency synchronization tracking stage consists of multiplying the received signal by a rotor which compensates the rotation of the constellation in each carrier in the frequency domain, for which the speed of the rotation of the constellation is calculated in each carrier

received.

15. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 14, characterized in that to calculate the speed of the rotation of the constellation of each carrier in reception, a grid is periodically sent during transmission in the downstream channel which obliges the head-end to use a fixed modulation, preferably a modulation with low signal to noise demodulation needs, in some carriers known as grid carriers whose position varies in time when these carriers are used to transmit information; so that the users know the position of the grid carriers and can undertake the process of line quality monitoring in these carriers knowing the modulation used by these, whether the user is the destination of the information sent by these grid carriers or not; with the characteristic that the users do not know a priori if they are the destination or not for the information modulated in these carriers.

16. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 15, characterized in that the maximum period for the grid is fixed beginning from the maximum rotation in the carrier with the greatest frequency, so as not to produce overflows, so that N_r is the period of the grid in symbols, that is, the maximum number of symbols between two consecutive measurements of the angle in a determined carrier, and the grid is distributed over the N carriers in the system requiring that all the carriers belong to the grid once during N_r symbols and that:

$$\sum_{i=1}^{N_r} N_{i=N}$$

where the sum of the number of carriers belonging to the grid during N_r symbols is equal to the total number of carriers in the system, where N_i is the number of carriers belonging to the grid in the symbol i ; so that following N_r symbols a new measure of the speed of the rotation in each one of the carriers is obtained.

17. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 15, characterized in that to calculate the speed of the rotation in reception the user demodulates the information sent by the grid carriers knowing a priori the modulation used by these, whether or not the user is the destination of the information being sent by the head-end, and calculates the rotation angles regarding the constellation transmitted, so that comparing these angles with the previous calculation for the same carriers and dividing by the time between both angle estimates, the rotation speed for these carriers is calculated.

18. PROCESS FOR SYNCHRONIZATION IN THE DOWNSTREAM OF MULTIPLE USERS IN A POINT TO MULTIPOINT SYSTEM WITH OFDM MODULATION, according to Claim 15, characterized in that in the tracking stage, frequency error is estimated by measuring the mean value of the rotated angle of the constellation of each one of the carriers in one symbol and this error is corrected by a frequency corrector element (27, 28), where this mean value is equivalent to the correlation angle.